BIOL 695

CALCIUM

Chapter 11
MENGEL et al, 5th Ed

Ca BEARING MINERALS

- Earth's crust ~ 3.64 % Ca
  - See Table 11.1 - Elemental comp of crust
  - Calcite $CaCO_3$
  - Dolomite $CaMg(CO_3)_2$
  - Dolomitic limestone $CaCO_3$ + $MgCO_3$
  - Apatite (most forms of calcium phosphate)
    - Dicalciumphosphate $CaHPO_4$
    - Tricalciumphosphate $Ca_3(PO_4)_2$

WEATHERING

- **Soil from unweathered limestone**
  10 - 20% Ca
- **Old highly weathered soils - Low Ca**
  - **Rate of weathering depends on formation of H^+ in soil**
- **Rate of Ca leaching can reach 200 - 300 kg/ha with rain fall**

WEATHERING

- **Higher with CO_2 present**
  $CaCO_3$ (insoluble) + CO_2 + H_2O $\Rightarrow$ $Ca(HCO_3)_2$ (soluble); thus leached
- **Carbonic acid from:**
  - **Root respiration**
  - **Rain water**
  - **OM respiration**
    - **Causes leaching**

NO_3 FORMATION LEACHES Ca

- $2NH_4^+ + 4O_2 \Rightarrow 2NO_3^- + 4H^+ + 2H_2O$
  - The H^+ used to release Ca from clay minerals
- Under conditions where nitrification can occur the appl of NH_4 fertilizers causes soil acidification & Ca^{2+} leaching
- NH_4NO_3 leaches Ca

ACID SOILS

- Often
  - Poor in structure
  - Low in Ca and Mg
  - High in Al and Mn
- Liming is way to maintain optimum pH

Ca ADSORPTION

- Ca^{2+} promotes flocculation of soil colloids & thus improves soil structure & stability of soil particles.
- Aggregates are formed
  - Have 40-50% soil volume = pore space
- Such soil stores water & air
  - Can be penetrated by roots

MONTMORILLONITE

- Exchangeable Ca is important for soil structure.
- 2:1 clay minerals like montmorillonitic clay should have 80% of soil exch capacity saturated with Ca^{2+}

KAOLINITE

- For kaolinite ~ 20% Ca^{2+} saturation is adequate because soils with this clay contains hydrous oxides which are even more effective than Ca^{2+} in flocculation.
- Adsorption sites of inorganic soil colloids not specific for Ca^{2+}

DIVALENCY

- Ca relatively strongly adsorbed to clay minerals because of electrostatic charge of Ca^{2+}
  - High due to divalency
  - Thin hydration shell (rel small)
- Adsorption bond of Ca^{2+} to organic colloids (humic acid) more specific

RELATIONSHIP/SOIL:SOLUTION

- Linear relationship between
  - Exchangeable Ca^{2+} in soil, and
  - Ca^{2+} in soil solution
  - Under equilibrium conditions

ECOLOGICAL ASPECTS

- Calcicoles - typical in calcareous soils
  - High levels of intracellular Ca
  - High conc of malate
- Calcifuges - typical in acid soils
  - Low in Ca
- What other characteristics of Ca-rich soils?

Fe CHLOROSIS

- Calcicoles have more prob with Al^{3+} than with lack of Ca^{2+}
- Calcifuges more susceptible to lime induced chlorosis (LIC) than calcicoles.
  - e.g.. Peaches and pecans
- LIC not due to lack of Fe uptake but
  - Inability of roots to metabolize Fe

Ca UPTAKE

- K^{+} uptake 10 times more efficient than Ca^{2+} uptake.
- Low Ca^{2+} uptake because only absorbed by young roots prior to Casparian strip formation
  - Anything that reduces root growth reduces Ca^{2+} absorption.
    - What are they?

Ca UPTAKE AT LOW SOIL LEVELS

- Ca^{2+} can be effective even if low in soil solution
  - Provided that K^+ & NH_4^+ are low.
- Ca^{2+} will detoxify heavy metal cations
- Ca^{2+} uptake by diocots > than monocots because of greater CEC sites (free carboxylic groups)

Ca UPTAKE PASSIVE

- Dependent on transpiration steam.
  - Ca^{2+} transport controlled by humidity.
  - BER causes
    - Drought
    - Water logged soil
    - NH_4^+ application
    - High salt concentration
    - Low temperature

Ca UPTAKE PASSIVE

- Growing points receive preferential amounts of Ca compared to older leaves even with less transpiration.
  - IAA stimulated proton efflux pump in elongation zones of shoot apex
    - Inc new cation exchange sites
      - Grow pt center for Ca^{2+} accum.

Ca IS IMMOBILE

- Once Ca^{2+} in older leaves cannot be mobilized to growing tips.
- Why doesn't Ca^{2+} move out?
  - No Ca^{2+} movement in phloem
    - Tissue supplied by phloem sap (fruit) has less Ca^{2+} than leaves.

BIOCHEMICAL FUNCTION OF Ca

- Ca^{2+} req in cell elongation & division
- EDTA removal of Ca^{2+} from tissue causes leakage.
  - Leak their contents $\Rightarrow$ necrosis
  - Ca deficiency
    - Ca^{2+} ordinarily forms chelates with phenols - with deficiency, phenols cause oxidation in cells

TIP BURN

- In absence of Ca, phenols can be oxidized to quinones
- + AA & protein = black compounds
- Leaf abscission

Ca FORMS

- Ca^{2+}
- Ca oxalates, carbonates, phosphates
- Adsorbed to carboxylic compounds
- Adsorbed to phenolic compounds
- Ca pectate / Phytic acid - seeds
- Why do plants fed with NO_3^- contain more Ca^{2+} than those fed with NH_4^+?

Ca DEFICIENCY

- Reduction in growth of meristem
- Necrosis in leaf margins in adv stage
- Becomes soft due to cell wall dissolu
- Brown sub accum in intracellular spa and in transport tissue / affect transp
- Not usual in soil but can occur in artificial media

STORAGE DISORDERS

- **Apple bitter pit**
  - **Surface pitted with small brown necrotic spots**
- **Tomato and watermelon blossom end rot**
- **Apple measles caused by complex**
  - **Low Ca, High Mn, Low B**

Ca IN CROP NUTRITION

- **pH and Ca effect**
  - **Acidification & leaching go hand in hand in humid areas.**
    - **Lime needed to neutralize soil**
    - **Ca improves soil structure**
    - **Neutral Ca salt ($CaSO_4{\cdot}H_2O$) replaces Na^+ with Ca^{2+} (salt spray and arid areas)**

Plant Nutrient Recovery Reduced by Soil Acidity

Soil pH	N	P	K
------ % Nutrient Recovery ------			
7.0	70	30	60
6.0	63	15	60
5.5	52	15	45
5.0	38	10	30
4.5	21	8	21

LIMING MATERIALS

- **$CaCO_3$ (1100°C) $\Rightarrow$ $CaO + CO$**
  - **In contact with water**

$CaO + H_2O \Rightarrow Ca(OH)_2$ = Hydrated Lime

  - **In contact with CO_2**

$Ca(OH)_2 + CO_2 \Rightarrow CaCO_3 + H_2O$ Time

- **Lime application and reaction in soil (text, sec 11.3.3)**

PARTICLE SIZE IMPORTANT

- An excellent analysis for lime is:
  - 30 mesh 99.5%
  - 50 mesh 99.3%
  - 70 mesh 96.8%
  - 100 mesh 91.4%
  - 140 mesh 84.8%
  - 200 mesh 72.2%
- $CaCO_3$ reacts slowly, however, more rapidly in very acid soil:

$$CaCO_3 + 2H^+ \Rightarrow Ca^{2+} + H_2O + CO_2$$

EFFECTIVE CALCIUM CARBONATE EQUIVALENT

- Effective Calcium Carbonate Equivalents (ECCE) - affected by the mesh size of limestone.
- Two sources (examples)
  - A = 95.52% ECCE
  - B = 69% ECCE

ECCE CALCULATION

- If 3 tons of 100% ECCE recommended:

  100 x 3 = 300

Source A 95.52 x A = 300

A = 300/ 95.52 = 3.14 Tons

Source B 69 x B = 300

B = 300/69 = 4.35 Tons